AMENDMENTS TO THE CLAIMS

1. (Currently Amended) An off-line feed rate scheduling method of a CNC machining process that is performed according to workpiece geometry and a given set of NC code provided from a CAD/CAM system, the method comprising:

selecting a constraint variable and inputting a reference value related to the constraint variable;

estimating a cutting configuration where a maximum constraint variable value (CVV) occurs through ME Z-map modeling;

obtaining the estimated cutting configuration and estimating a specific rotation angle (φ_S) where the maximum constraint variable value occurs through constraint variable modeling;

calculating a feed rate that satisfies the reference value ~~of~~ related to the constraint variable at the estimated specific rotation angle; and

applying the calculated feed rate to the NC code.

2. (Original) The method of claim 1, wherein the calculating a feed rate comprises:

inputting specific feed rates f_1 and f_2 ($f_1 < f_2$);

calculating maximum constraint variable values CVV_1 and CVV_2 corresponding to the feed rates f_1 and f_2, respectively, at the specific rotation angle;

approximating a feed rate f_{next} that corresponds to a reference value RV of a constraint variable value using the formula,

$$f_{next} = f_1 + \frac{(RV - CVV_1)(f_2 - f_1)}{CVV_2 - CVV_1};$$

calculating a constraint variable CVV_{next} in the case where the feed rate is f_{next}; and

determining using the formula below if the constraint variable value CVV_{next} when compared to the reference value RV is less than an error limit, applying the feed rate f_{next} to the NC code when it is less than the error limit, replacing the feed rate f_2 by f_{next} and repeating the process of obtaining f_{next} when this value is not less than the error limit and the reference value RV is greater than the constraint variable value CVV_{next}, and replacing the feed rate f_1 by f_{next} and repeating the process of obtaining

f_{next} when this value is not less than the error limit and the reference value is not greater than the constraint variable value CVV_{next},

where

$$\frac{CVV_{next} - RV}{RV} < \text{Error Limit}$$

3. (Currently Amended) The method of claim 1, wherein computing cutting configurations through ME Z-map modeling comprises:

searching for node points located in a cutting area;

identifying whether a target node is an edge node ~~(a node closest to a cutter edge)~~ or not;

calculating and updating a height value of each node in the cutting area;

moving a target node if it is an edge node and storing movement direction angles;

computing the cutting configurations using the stored angles.

4. (Currently Amended) The method of claim 3, wherein the cutting configurations computed through ME Z-map modeling include <u>at least one of</u> an entry angle, an exit angle, <u>and</u> an axial depth of cut ~~and so on~~.

5. (Original) The method of claim 3, wherein in the case where a difference between a distance from a tool center to a target node and a tool radius is smaller than a movement limit, this node is designated as an edge node.

6. (Original) The method of claim 1, wherein one of cutting force and machined surface error is selected as a constraint variable.

7. (Currently Amended) An off-line feed rate scheduling method for adjusting a cutting force of a CNC machining process that is performed according to workpiece geometry and a given set of NC code instructing paths of a tool provided from a CAD/CAM system, the method comprising:

inputting a reference cutting force;

estimating a cutting configuration where a maximum cutting force occurs through ME Z-map modeling;

receiving the estimated cutting configuration and estimating a specific rotation angle where the maximum cutting force occurs through cutting force modeling;

calculating a feed rate that satisfies the reference cutting force at the estimated specific rotation angle; and

applying the calculated feed rate to the NC code.

8. (Currently Amended) The method of claim 7, wherein the reference cutting force is selected from a reference cutting force RF_1 established to prevent breaking of a tool shank, and a reference cutting force RF_2 established to prevent damage to an edge portion of a tool, RF_1 and RF_2 being calculated by the formulae

$$RF_1 = SF \cdot TRS \cdot S_1$$

$$RF_2 = SF \cdot TRS \cdot S_2$$

where RF_1 represents the reference cutting force considered to avoid breakage of tool shank and RF_2 indicates the reference cutting force to prevent breakage of tool edge; *SF* means safety factor, which is used to make up for unpredictable factors ~~such as cutter geometry error or cutter material variation~~; and TRS means transverse rupture strength of ~~the~~ a tool material.

9. (Currently Amended) The method of claim 7, wherein the tool is a flat end milling tool, and cutting force components of each axial direction of three-dimensional Cartesian coordinate according to a rotational angle of the tool are obtained using

$$F_x(j) = \sum_k \sum_i F_x(i,j,k)$$

$$F_y(j) = \sum_k \sum_i F_y(i,j,k)$$

$$F_z(j) = \sum_k \sum_i F_z(i,j,k)$$

where

$$F_x(i,j,k) = [C_1 K_n \cos(\phi - \alpha_r) + K_f K_n C_3 \cos\phi - K_f K_n C_4 \sin(\phi - \alpha_r)] t_c(\phi) B_1$$

$$F_y(i,j,k) = [C_1 K_n \sin(\phi - \alpha_r) + K_f K_n C_3 \sin\phi + K_f K_n C_4 \cos(\phi - \alpha_r)] t_c(\phi) B_1$$

$$F_z(i,j,k) = [-C_2 K_n + K_f K_n C_5] t_c(\phi) B_1$$

and where C_1, C_2, C_3, C_4, and C_5 in the above are calculated by the following:

$$C_1 = \frac{\cos\theta_h}{\sin\theta_{tk}}, \quad C_2 = \frac{\sin\theta_h}{\sin\theta_{tk}} \cdot \cos\alpha_r$$

$$C_3 = \sin\theta_h(\sin\theta_c - \cos\theta_c \cot\theta_{tk})$$

$$C_4 = \frac{\cos\theta_c}{\sin\theta_{tk}}$$

$$C_5 = \cos\theta_h(\sin\theta_c - \cos\theta_c \cot\theta_{tk})$$

and

$$\cos\theta_{th} = \sin\alpha_r \cdot \sin\theta_h$$

where i is a cutter tooth index, j is an index of a cutter rotation angle, k is an index of a z-axis disk element, φ is an angle position of a cutter edge, α_r is a rake angle, $t_c(\varphi)$ is uncut chip thickness, θ_h is a helix angle, θ_c is a chip flow angle, and K_n, K_f, and B_1 are constants.

10. (Currently Amended) The method of claim 9, wherein K_n, K_f, and θ_c may be obtained by the following formulae,

$$\ln(K_n(i,j,k)) = A_1 - (A_1 - A_2)e^{-(A_3 t_c(i,j,k))^{A_4}}$$

$$K_f(i,j,k) = B_1 - (B_1 - B_2)e^{-(B_3 t_c(i,j,k))^{B_4}}$$

$$\theta_c(i,j,k) = C_1 - (C_1 - C_2)e^{-(C_3 t_c(i,j,k))^{C_4}}$$

where A_1, A_2, A_3, A_4, B_1, B_2, B_3, B_4, C_1, C_2, C_3, and C_4 are constants.

11. (Currently Amended) The method of claim 7, wherein the tool is a ball end milling tool, and cutting force components of each axial direction of three-

dimensional Cartesian coordinate according to a rotational angle of the tool are obtained using

$$\begin{Bmatrix} F_x \\ F_y \\ F_z \end{Bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{Bmatrix} K_1 \\ K_2 \\ K_3 \end{Bmatrix}$$

where

$$K_1 = K_n$$

$$K_2 = \cos\theta_c K_n K_f$$

$$K_3 = \sin\theta_c K_n K_f$$

$$A_{11} = B_1 \sum_k \sum_i (\cos\alpha_r \cos\phi \cos\theta_h + \sin\alpha_r \sin\phi) \cdot t_c(\phi)$$

$$A_{12} = B_1 \sum_k \sum_i (\sin\alpha_r \frac{1}{f_2} \cos\phi \cos\theta_h - \frac{1}{f_2} \cos\alpha_r \sin\phi - \frac{f_1}{f_2} \cos\alpha_r \cos\phi \sin\theta_h) \cdot t_c(\phi)$$

$$A_{13} = B_1 \sum_k \sum_i (-\frac{f_1}{f_2} \sin\phi + \frac{1}{f_2} \cos\phi \sin\theta_h) \cdot t_c(\phi)$$

$$A_{21} = B_1 \sum_k \sum_i (\cos\alpha_r \sin\phi \cos\theta_h - \sin\alpha_r \cos\phi) \cdot t_c(\phi)$$

$$A_{22} = B_1 \sum_k \sum_i (\sin\alpha_r \frac{1}{f_2} \sin\phi \cos\theta_h + \frac{1}{f_2} \cos\alpha_r \cos\phi - \frac{f_1}{f_2} \cos\alpha_r \sin\phi \sin\theta_h) \cdot t_c(\phi)$$

$$A_{23} = B_1 \sum_k \sum_i (\frac{f_1}{f_2} \cos\phi + \frac{1}{f_2} \sin\phi \sin\theta_h) \cdot t_c(\phi)$$

$$A_{31} = B_1 \sum_k \sum_i (-\sin\theta_h \cos\alpha_r) \cdot t_c(\phi)$$

$$A_{32} = B_1 \sum_k \sum_i (-\sin\alpha_r \frac{1}{f_2} \sin\theta_h - \frac{f_1}{f_2} \cos\alpha_r \cos\theta_h) \cdot t_c(\phi)$$

where i is a cutter tooth index, j is an index of a cutter rotation angle, k is an index of a z-axis disk element, φ is an angle position of a cutter edge, α_r is a rake angle, $t_c(\varphi)$ is uncut chip thickness, θ_h is a helix angle, θ_c is a chip flow angle, and K_n, K_f, B_1, f_1 and f_2 are constants.

12. (Currently Amended) The method of claim 11, wherein K_n, K_f, and θ_c may be obtained by the following formulae:

$$K_n = K_1$$

$$\theta_c = \tan^{-1}(\frac{K_3}{K_2})$$

$$K_f = \frac{K_2}{\cos\theta_c K_n}$$

<u>where K_1, K_2 and K_3 are constants</u>.

13. (Original) An off-line feed rate scheduling method for adjusting a machined surface error of a CNC machining process that is performed according to workpiece geometry and a given set of NC code provided from a CAD/CAM system, the method comprising:

inputting a reference surface error;

estimating a cutting configuration where a maximum surface error occurs through ME Z-map modeling;

receiving the estimated cutting configuration and estimating a specific rotation angle where the maximum surface error occurs through machined surface error modeling;

calculating a feed rate that satisfies the reference surface error at the estimated specific rotation angle; and

applying the calculated feed rate to the NC code.

14. (Original) The method of claim 13, wherein the tool is a flat end milling tool, and a cusp error C_h is calculated using the formula

$$C_h = R - \sqrt{R^2 - (\frac{f_t}{2})^2}$$

where R is a tool radius and f_t is an edge feed rate.

15. (Currently Amended) The method of claim 13, wherein the tool is a ball end milling tool, and a cusp error C_h is calculated using the formula,

$$C_h = R - \sqrt{R^2 - (\frac{D}{2})^2}$$

where $D = \sqrt{(TPD^2 + f_t^2)}$, TPD being an interval between a tool path, R being a tool radius and f_t being an edge feed rate.